NACA4409 airfoil

MEK4470

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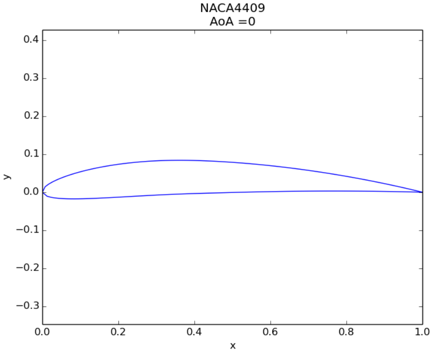
NACA geometry

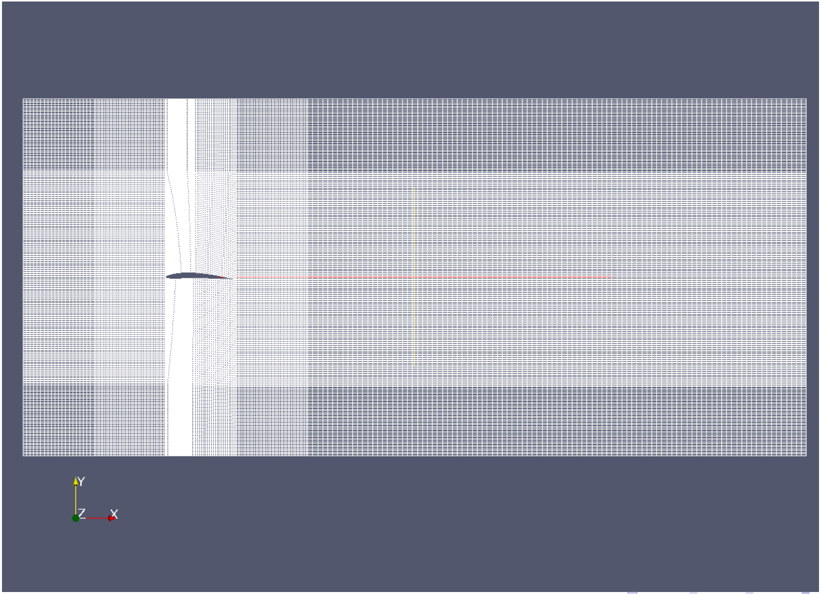
- Geometry from formula
- Python script: Angle of attack, spline, blockMeshdict, loop



Benchmark

- Two reports, same airfoil, different conditions:
  - US department of energy (Re: 0.5e+06, q = 277.7 Pa, M = 0.09)
  - NACA report no. 669 (Re: 8e+06, v: 21 m/s)

Mesh



RANS models

For external flow, the most suitable models are:

- The Spalart-Allmaras
- SST $k - \omega$

Solves the transport equation for kinematic eddy viscosity, $\tilde{\nu}$.

Boundary conditions and initial conditions
I've used free stream values at all boundaries, except at the airfoils wall.

Because of high Reynolds number:

$$\tilde{\nu} = \nu_t$$

Boundary conditions and initial conditions
I've tried two approximations for the turbulent viscosity, ν_t. One based on guidelines, the second based on other CFD-airfoil experiments.

$$\nu_t = \sqrt{kL^2} = \sqrt{0.1U^2L^2} = \sqrt{0.1}UL \quad (1)$$

Where L is the chord length

$$\nu_t = 0.1\nu \quad (2)$$

Parameters fitted to match USDE report

Freestream

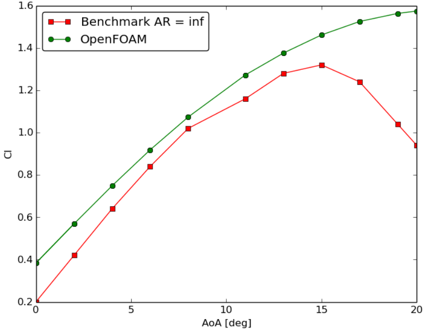
Approach:	**1**	**2**
$\nu_t = \tilde{\nu}$	$2.95\ m^2/s$	$1.6287e-06\ m^2/s$
U	30.6 m/s	26.7 m/s
ρ	$0.7\ kg/m^3$	$0.8\ kg/m^3$
c	0.305 m	0.305m

airfoil

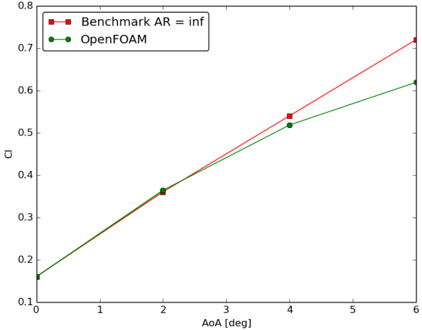
Approach:	**1**	**2**
ν_t-wall function	0	0
$\tilde{\nu}$	0	0
U	0 m/s	0 m/s

Lift coefficients

(a) 1



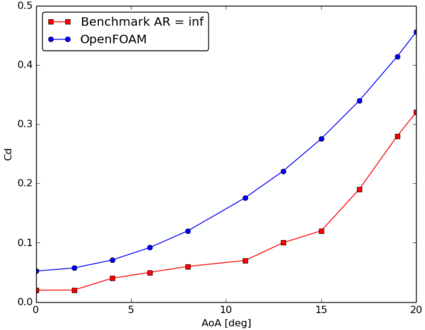
(b) 2



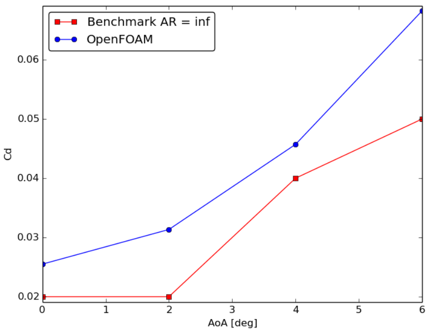
1: Does not work well for post stall and lower AoA's
2: Trouble with convergence at higher AoA's. Works well at lower AoA's

Drag coefficient

(a) 1

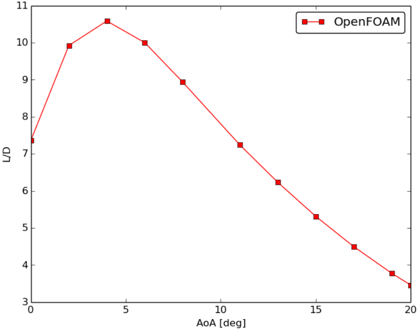


(b) 2

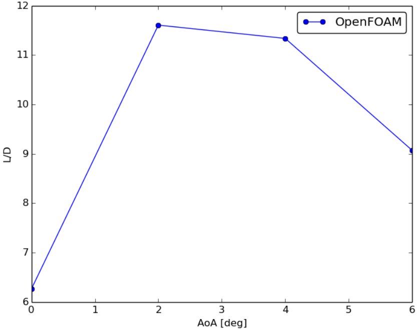


Lift/Drag

(a) 1



(b) 2



SST k-ω

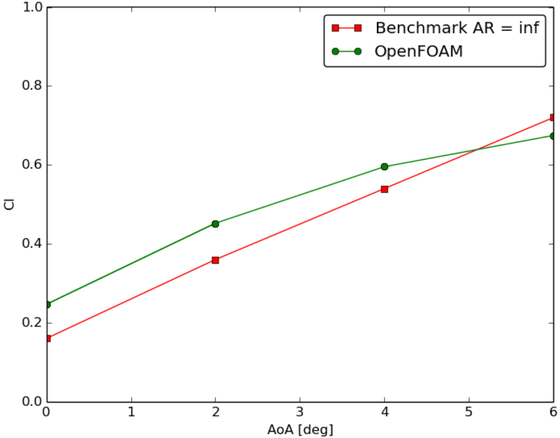
Two eqa. solver

SST k-ω

Parameters fitted to USDE report:

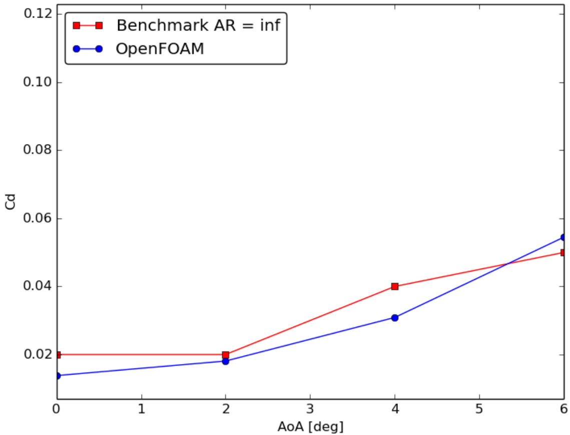
- $\nu_t = \tilde{\nu} = 1.6287e-06 \; m^2/s$,
- U = 26.7 m/s
- $\rho = 0.8 \; kg/m^3$
- k = 0.1$U^2 I^2$ =0.2737
- $\omega = \frac{0.09k}{\beta\nu}$
- c = 0.305 m

Lift coefficients



Trouble with convergence at higher AoA's. Works well at lower AoA's

Drag coefficients



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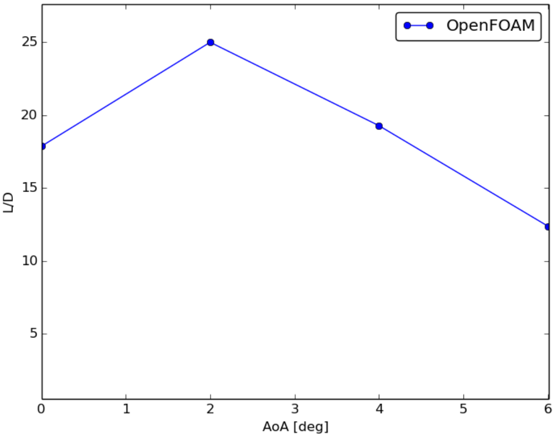
Lift/Drag



Trouble with convergence at higher AoA's. Works well at lower AoA's

Finite volume schemes

Term	Spalart-Allmaras
d/dt	Steady state
Convection	bounded Gauss linearUpwind
Diffusion	bounded Gauss linearUpwind
Remaining	Left as default

Term	SST k-ω
d/dt	Steady state
Convection	bounded Gauss linearUpwind
Diffusion	bounded Gauss upwind
Remaining	Left as default

Summary

- Models works well for low angles of attack
- Convergence trouble at higher AoA's